

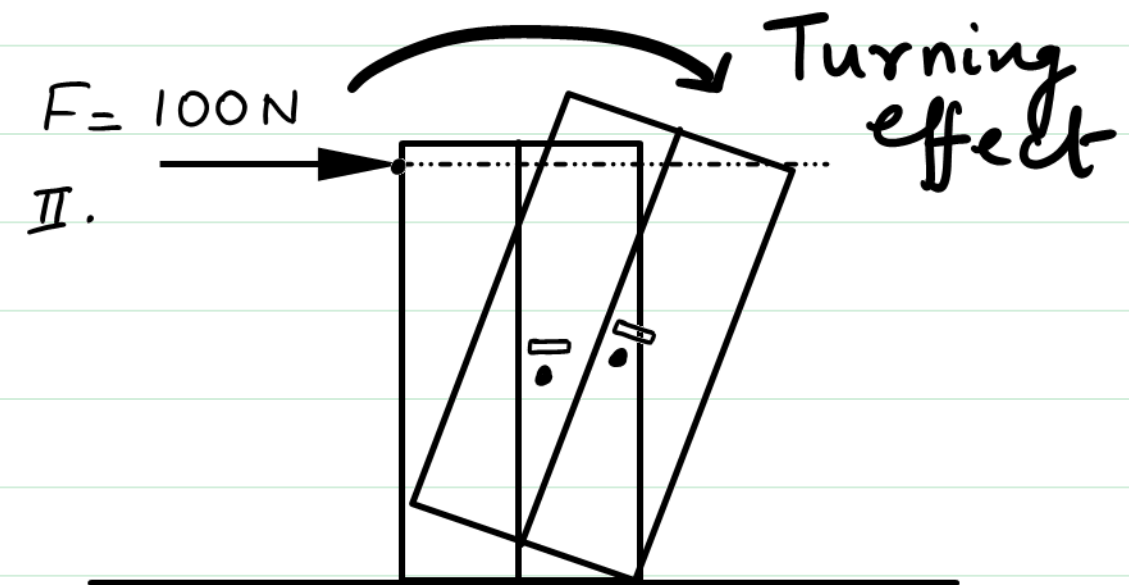
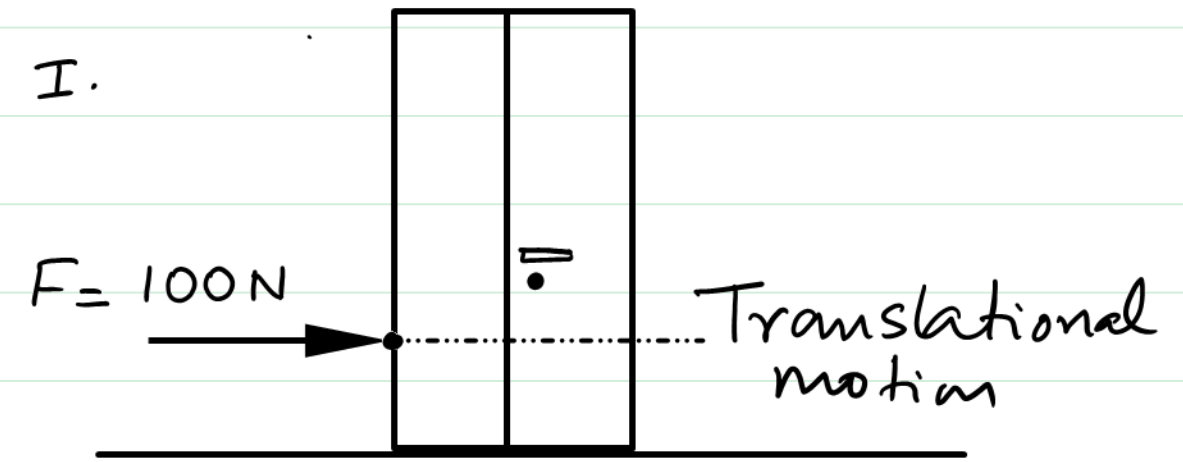
Moment of a Force or Torque (Turning effect of a force)

The location of line of application of force on a body determines if the motion will be

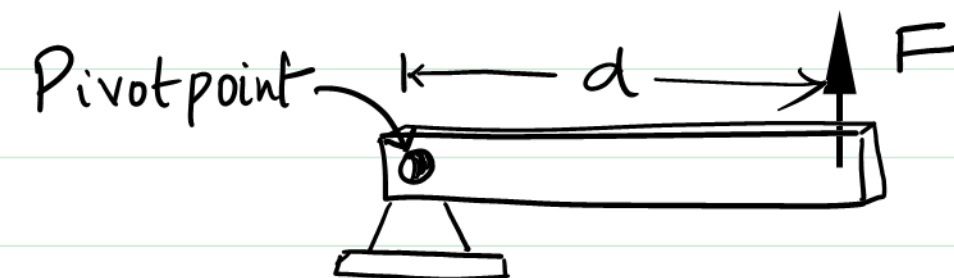
- Translational or
- Rotational

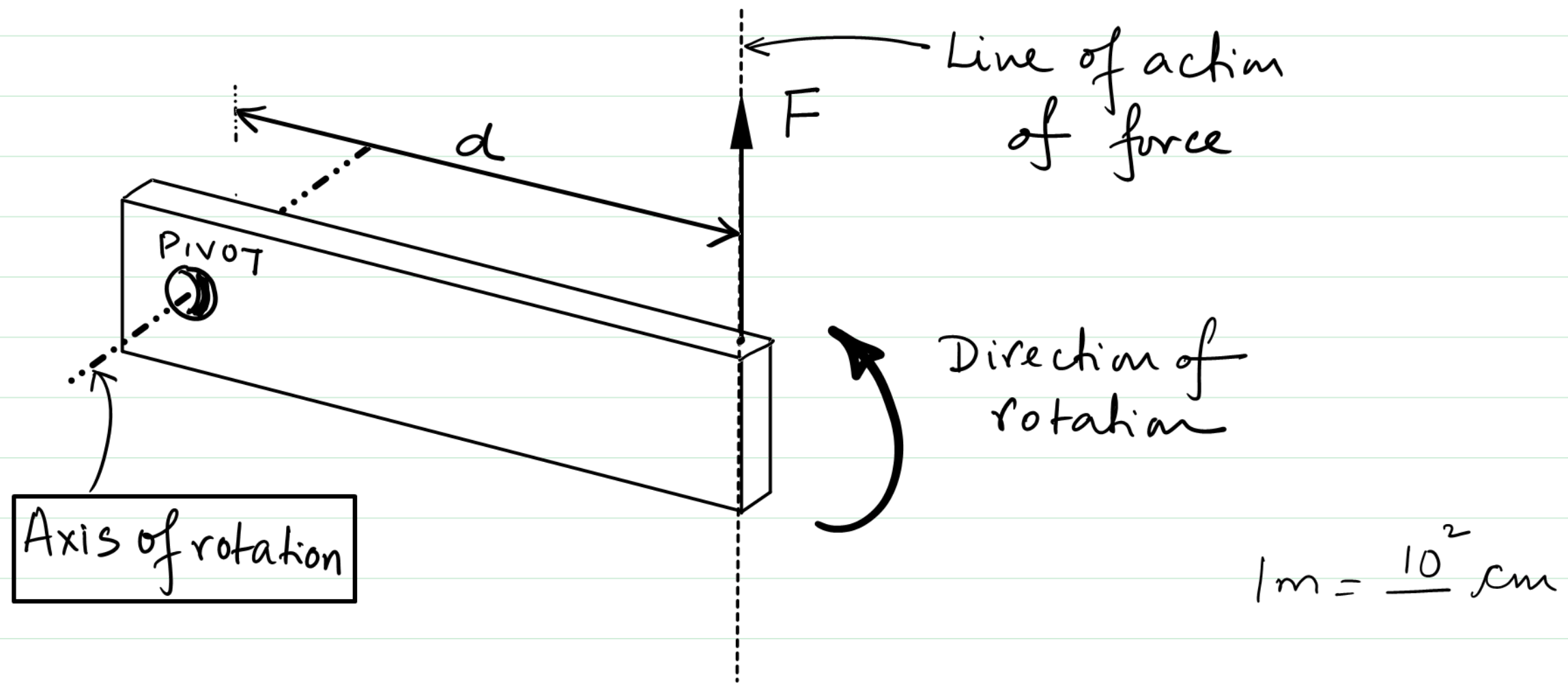
In Case I. The body translates

In Case II. The body rotates



Moment of a force : Is defined as the product of the magnitude of force and perpendicular distance of the line of action of force from the axis of rotation.
or
Torque.





$$\text{Moment of force about Pivot} = F \times d$$

S.I. units of moment of force $\rightarrow \text{N m}$

C.G.S. units of moment of force $\rightarrow \text{dyne cm}$

$1\text{N-m} = 10^5 \text{dyne} \cdot 10^2 \text{cm} \Rightarrow 1\text{N-m} = 10^7 \text{dyne-cm}$ *

Gravitational units $\rightarrow 1\text{kgf m} = 9.8\text{N-m}$ *

$1\text{gf cm} = 980 \text{dyne-cm}$ *

6. Fig. 1.30 shows two forces each of magnitude 10 N acting at the points A and B at a separation of 50 cm, in opposite directions. Calculate the resultant moment of the two forces about the point (i) A, (ii) B and (iii) O situated exactly at the middle of the two forces.

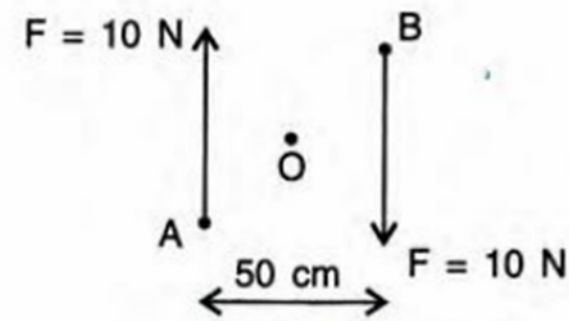


Fig. 1.30

(i) Resultant Moment about A

$$= -(\cancel{F_A \times 0m}) + (-F_B \times \frac{50}{100})$$

$$= -10 \times \frac{50}{100}$$

$$\Sigma M_A = -5Nm = \boxed{5Nm \text{ clockwise}}$$

(ii) Resultant Moment about B

$$= -(F_A \times \frac{50}{100}) + (\cancel{-F_B \times 0})$$

$$= -(10 \times \frac{50}{100})$$

$$\Sigma M_B = -5Nm = \boxed{5Nm \text{ Clockwise}}$$

$$\Sigma M_O = -\left(F_A \times \frac{25}{100}\right) + \left(-F_B \times \frac{25}{100}\right)$$

$$= -\left(10 \times \frac{25}{100}\right) + \left(-10 \times \frac{25}{100}\right)$$

$$= -2.5 - 2.5$$

$$= -5Nm$$

$$= \boxed{5Nm \text{ clockwise}}$$

7. A steering wheel of diameter 0.5 m is rotated anticlockwise by applying two forces each of magnitude 6 N. Draw a diagram to show the application of forces and calculate the moment of the forces applied.
Ans. 2.5 N m



$$\begin{aligned}\text{Moment of couple} &= \text{Either force} \times \perp^r \text{ dist} \\ &= 6\text{ N} \times 0.5\text{ m} \\ &= \boxed{3\text{ Nm}}\end{aligned}$$

8. A uniform metre rule is pivoted at its mid-point. A weight of 50 gf is suspended at one end of it. Where should a weight of 100 gf be suspended to keep the rule horizontal?

Ans. At distance 25 cm from the other end.



As per Principle of Moments.

$$50\text{ gf} \times 50\text{ cm} = (100\text{ gf}) \times x\text{ cm}$$

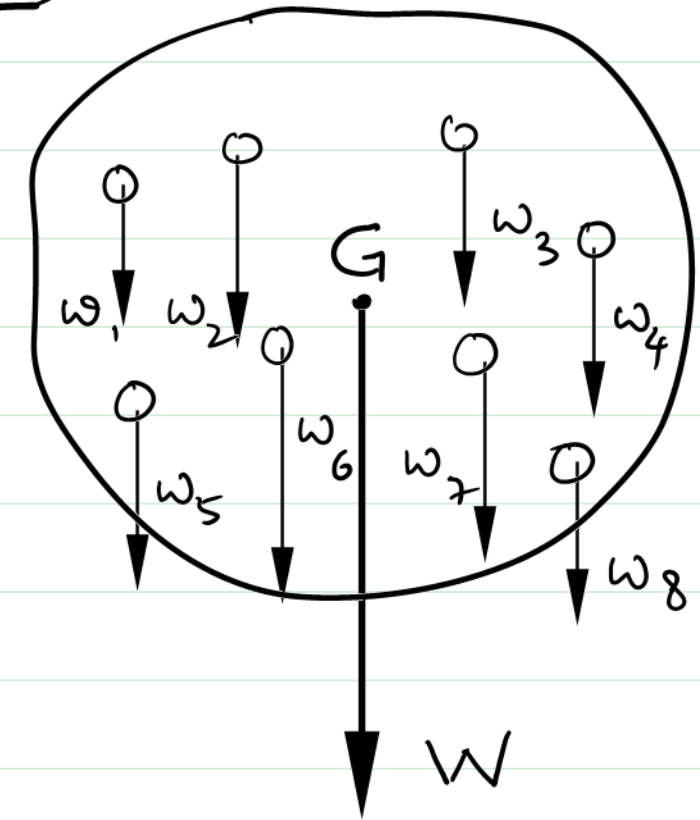
$$x = \frac{50 \times 50}{100} \frac{\text{gf cm}}{\text{gf}}$$

$$x = 25\text{ cm}$$

100 gf should be suspended 25 cm to the right of pivot.

Concept of C.G. (C.G. is also called as Centre of Mass)

- Each body consists of large number of particles.
- Let weight of particles be $w_1, w_2, w_3, \dots$
- The weights act downward as forces which are parallel to each other.
- The sum of all such forces can be equated to $W = w_1 + w_2 + w_3 + \dots$
- This equivalent force W is assumed to act at a point 'G'.
- The algebraic sum of moments of weights $w_1, w_2, w_3, \dots$ about point G is zero.
- 'G' is the centre of gravity of the body.



Conditions for work done by a force to be zero.

- (i) when $\vec{s} = 0$
- (ii) when $\theta = 90^\circ$ b/w $\vec{F}$ and $\vec{s}$.

Work Done by force of Gravity

(i) On a falling object

$$W = mgh$$

mg = Weight (Force)
 h = displacement.

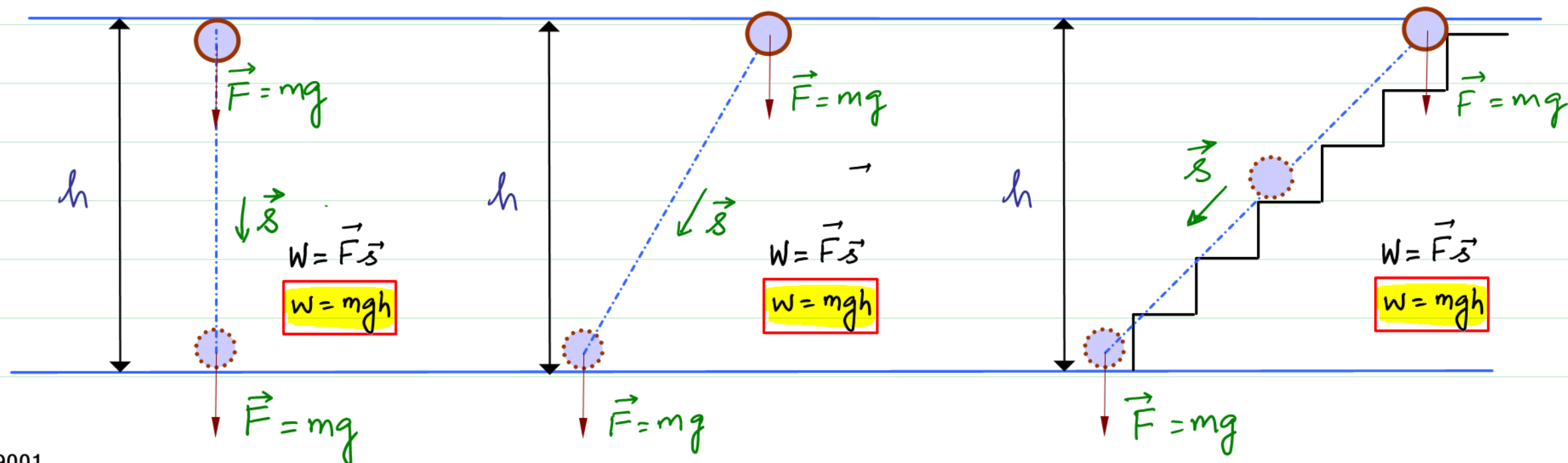
(ii) On an object thrown up

$$W = -mgh$$

Here $\vec{s} \uparrow$ while $\vec{F} \downarrow$ i.e. mg

NOTE: Work done by the force of gravity on a falling object or an object thrown up does not depend on the path taken.

Object falls under gravity



Conversion of P.E. into K.E.

Potential energy changes in kinetic energy whenever it is put into use.

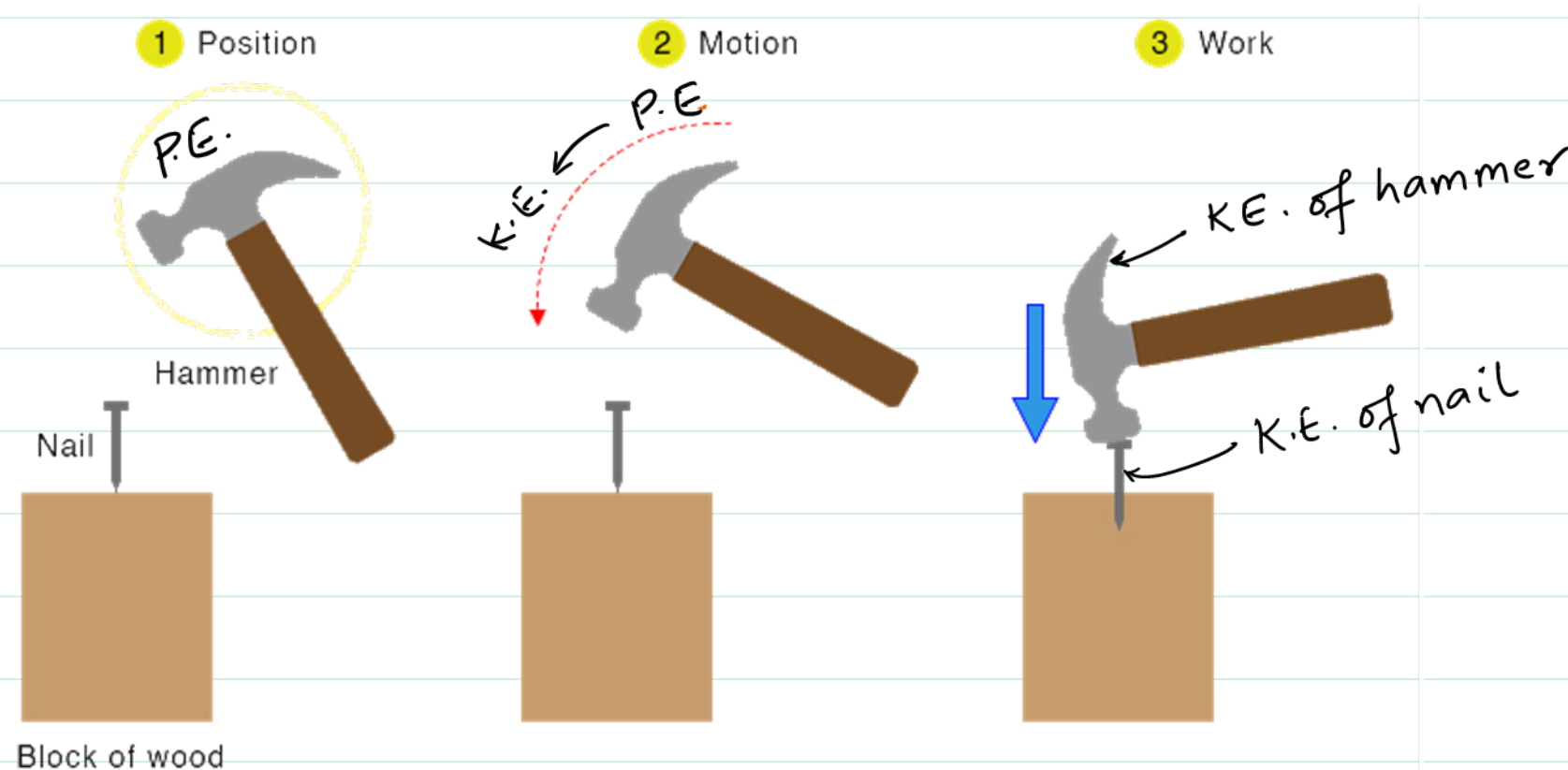
Examples :

1. Hammer and Nail :

A hammer in its raised position has *gravitational P.E. equal to mgh* .

As the hammer is brought down, its P.E. begins to change into K.E., the falling hammer having both P.E. and K.E.

Upon striking the nail, the hammer does work on the nail, during which the K.E. of the hammer changes into the K.E. of the nail, due to which the nail gets driven into the wooden piece.



2. A wound up spring watch :

A wound up watch spring has *Elastic P.E.*

The stored P.E. is equal to the work done on it by winding it up.

As the spring begins to unwind, its P.E. changes into K.E. which does work in turning the hands of the watch.

The K.E. of the spring now converts into the K.E. of the hands of the watch.



7. A water pump raises 50 litre of water through a height of 25 m in 5 s. Calculate the power of the pump used (assuming 100% efficiency).

(Take $g = 10 \text{ N kg}^{-1}$ and density of water = 1000 kg m^{-3}).
Ans. 2500 W

Given:
 $\text{vol. of water} = 50 \text{ l}$
 $h = 25 \text{ m}$
 $t = 5 \text{ s}$
 $\text{Mass of water} = 50 \text{ kg}$

$$\rho_w = 1000 \text{ kg m}^{-3}$$

$$\begin{aligned} 1 \text{ m}^3 &= 1000 \text{ kg} \\ \downarrow \\ 1000 \text{ l} &= 1000 \text{ kg} \\ 50 \text{ l} &= \frac{1000}{1000} \times 50 \\ &= \underline{50 \text{ kg}} \end{aligned}$$

$$\begin{aligned} \text{Work done by pump to raise water} &= mgh \\ &= 50 \text{ kg} \times 10 \frac{\text{N}}{\text{kg}} \times 25 \text{ m} \\ &= 12500 \text{ J} \end{aligned}$$

$$P = \frac{W}{t} = \frac{12500}{5} \Rightarrow \boxed{P = 2500 \text{ W}}$$

8. A pump is used to lift 600 kg of water from a depth of 75 m in 10 s. Calculate :

- (a) the work done by the pump,
 (b) the power at which the pump works, and
 (c) the power rating of the pump if its efficiency is 40%. (Take $g = 10 \text{ m s}^{-2}$)

[Hint : Efficiency = $\frac{\text{useful power}}{\text{power input}}$] output power

Given: $\text{mass of water} = 600 \text{ kg}$
 $\text{Wt. of water} = mg = 600 \times 10 = 6000 \text{ N}$
 $\therefore \text{Force} = 6000 \text{ N}$
 $g = 10 \text{ m s}^{-2}$
 $\text{displacement} \quad h = 75 \text{ m}$
 $\text{time} \quad t = 10 \text{ s}$

(i) $W = Fs = 6000 \times 75 = \boxed{450000 \text{ J}}$

(ii) $P = \frac{W}{t} = \frac{450000}{10} = \boxed{45000 \text{ W}} \text{ or } \boxed{45 \text{ kW}}$

(iii) $\frac{40}{100} = \frac{45 \text{ kW}}{\text{Input power}} \Rightarrow \boxed{\text{Power Rating} = 112.5 \text{ kW}}$

Power Rating is the Power Input
 Actual power due to work done is Power output

16. A cannon ball of mass 500 g is fired with a speed of 15 m s^{-1} . Find : (i) its kinetic energy, and (ii) its momentum. **A**

$$m = 500 \text{ g} = 0.5 \text{ kg} \quad v = 15 \text{ m s}^{-1}$$

$$(i) K = \frac{1}{2} m v^2 = \frac{1}{2} \times 0.5 \times 15 \times 15 = 56.25 \text{ J}$$

$$(ii) p = m v \Rightarrow p = 0.5 \times 15 = 7.5 \text{ kg m s}^{-1}$$

17. A body of mass 10 kg is moving with a velocity of 20 m s^{-1} . If the mass of the body is doubled and its velocity is halved, find : (i) the initial kinetic energy, and (ii) the final kinetic energy.

Case 1

Case 2

Mass 10 kg
Velocity 20 m s⁻¹
K.E. K_i

20 kg
10 m s⁻¹
 K_f

$$K_i = \frac{1}{2} \times 10 \text{ kg} \times 20 \times 20 = 2000 \text{ J}$$

$$K_f = \frac{1}{2} \times 20 \text{ kg} \times 10 \times 10 = 1000 \text{ J}$$

18. A truck weighing 1000 kgf changes its speed from 36 km h^{-1} to 72 km h^{-1} in 2 minutes. Calculate : (i) the work done by the engine, and (ii) its power. ($g = 10 \text{ m s}^{-2}$).

Work Done = Change in KE

$$\frac{36 \times 5}{18} = 10$$

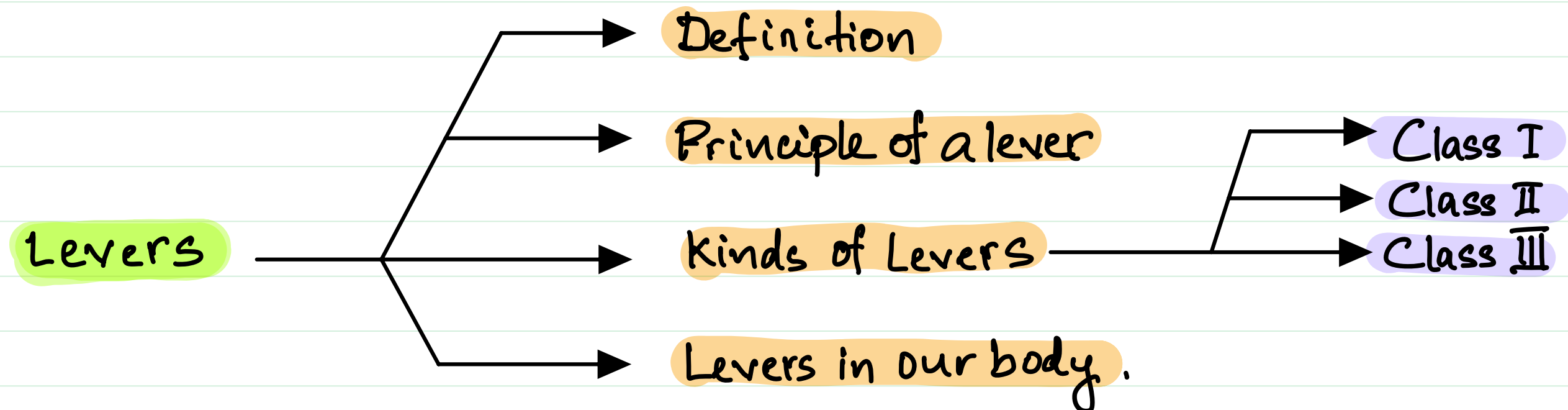
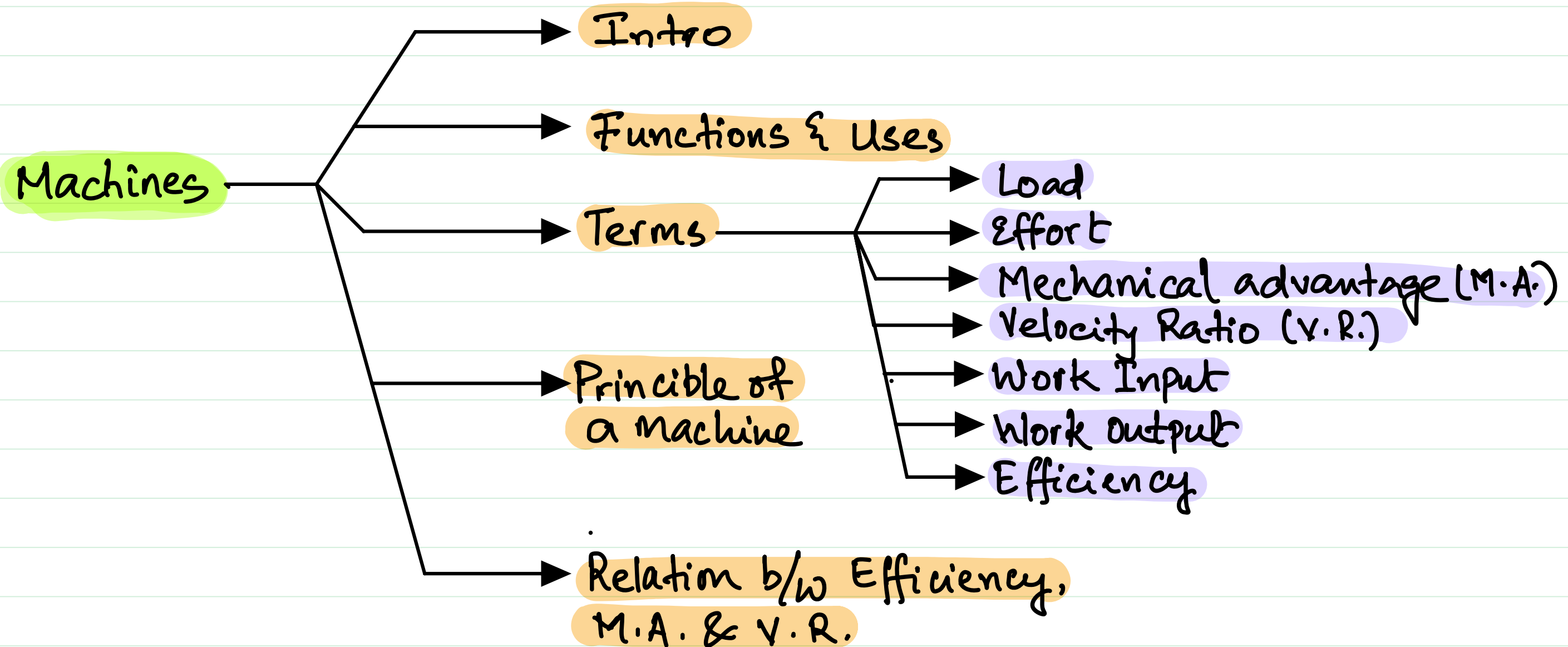
$$u = 36 \text{ km h}^{-1} = 10 \text{ m s}^{-1}; v = 72 \text{ km h}^{-1} = 20 \text{ m s}^{-1}$$

$$\text{Weight} = 1000 \text{ kgf} \Rightarrow m = 1000 \text{ kg}, t = 120 \text{ s}$$

$$(i) W = K_f - K_i \Rightarrow W = \frac{1}{2} m (v^2 - u^2) = \frac{1}{2} \times 1000 \text{ kg} (20^2 - 10^2) = 150000 \text{ J}$$

$$(ii) P = \frac{W}{t} = \frac{150000}{120} = 1250 \text{ W}$$

(A) MACHINES, TERMS AND LEVERS



Principle of a machine

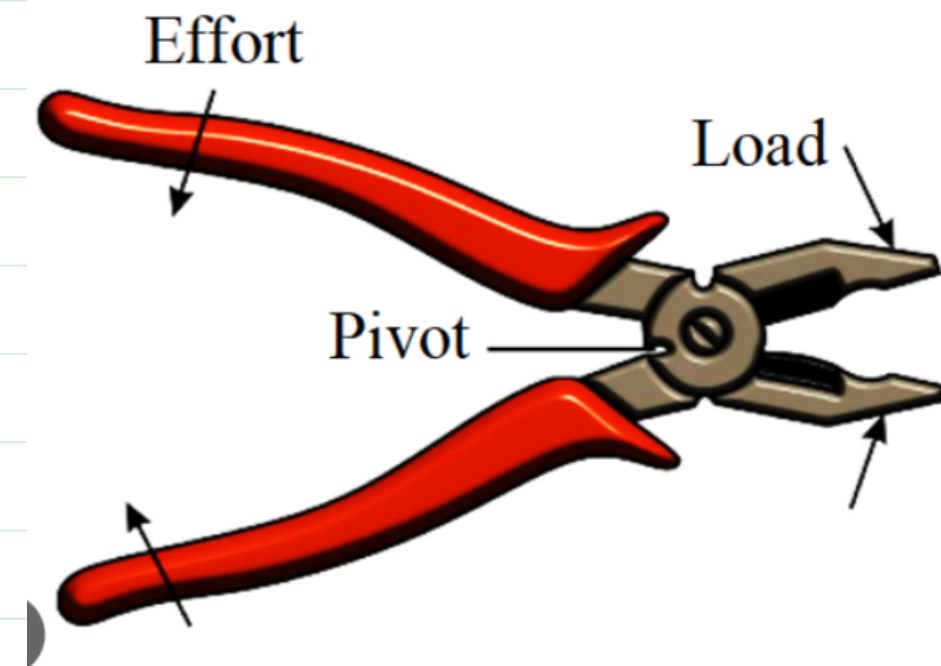
Effort Point : The point at which energy is supplied to the machine is called Effort Point.

Load Point : The point where energy is obtained by overcoming the load is called Load point.

For a perfect or Ideal machine,

$$\text{Work done on machine} = \text{Work done by machine}$$

$$\text{Input} = \text{Output}$$



This is called the Principle of machine, which is based on the Law of Conservation of Energy.

Ideal machine - A machine whose parts are weightless and frictionless such that, work done on it = work done by it.